



Superconducting Materials for the Next Generation Colliders

VLHC Magnet Technologies Workshop

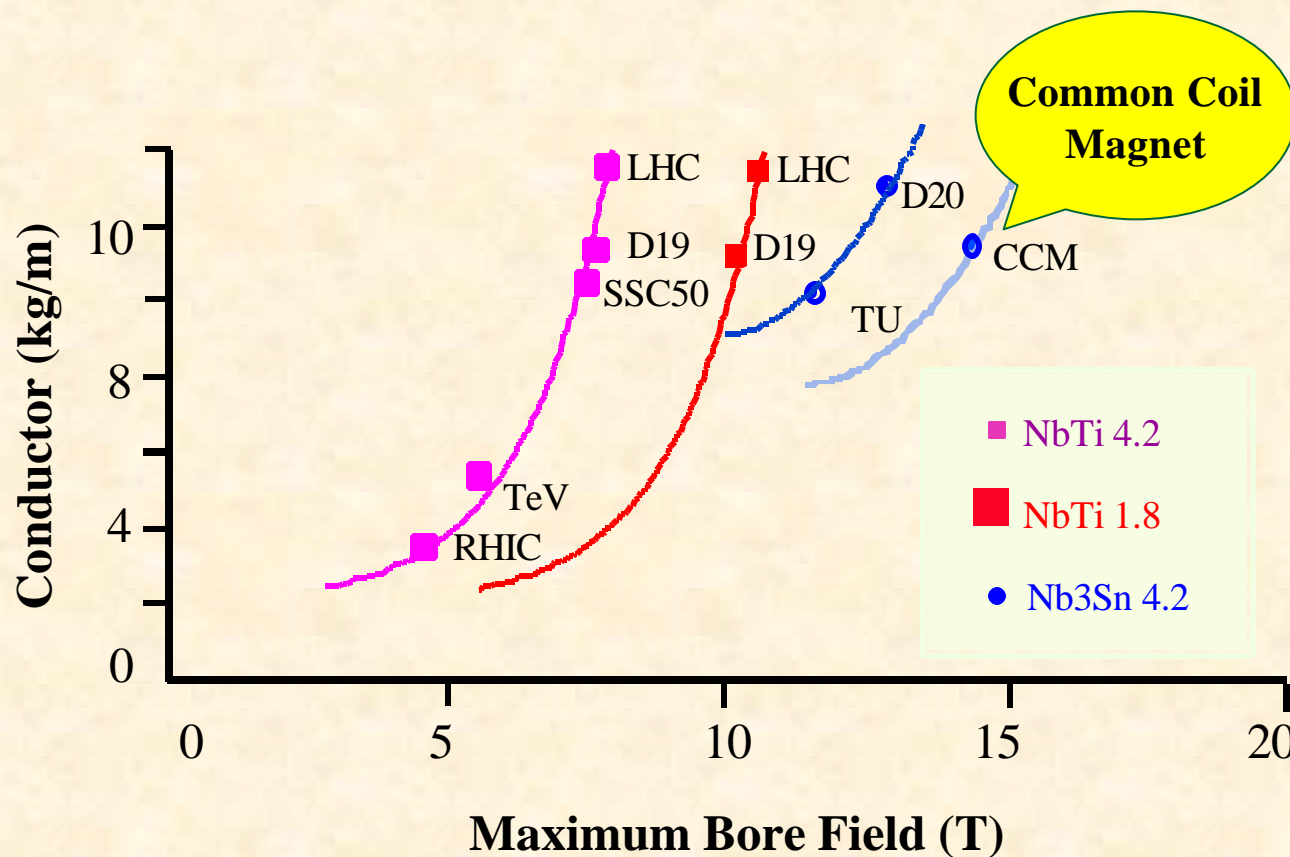
May 24-26, 2000

Ron Scanlan

for the Conductor Development Group



Better materials & simpler coil geometry reduce conductor use



The goal of the National Conductor Program is superior A15 conductor in industrial quantities @ lower \$/kg



Superconductor for HEP Magnets

I. New HEP Conductor Development Program

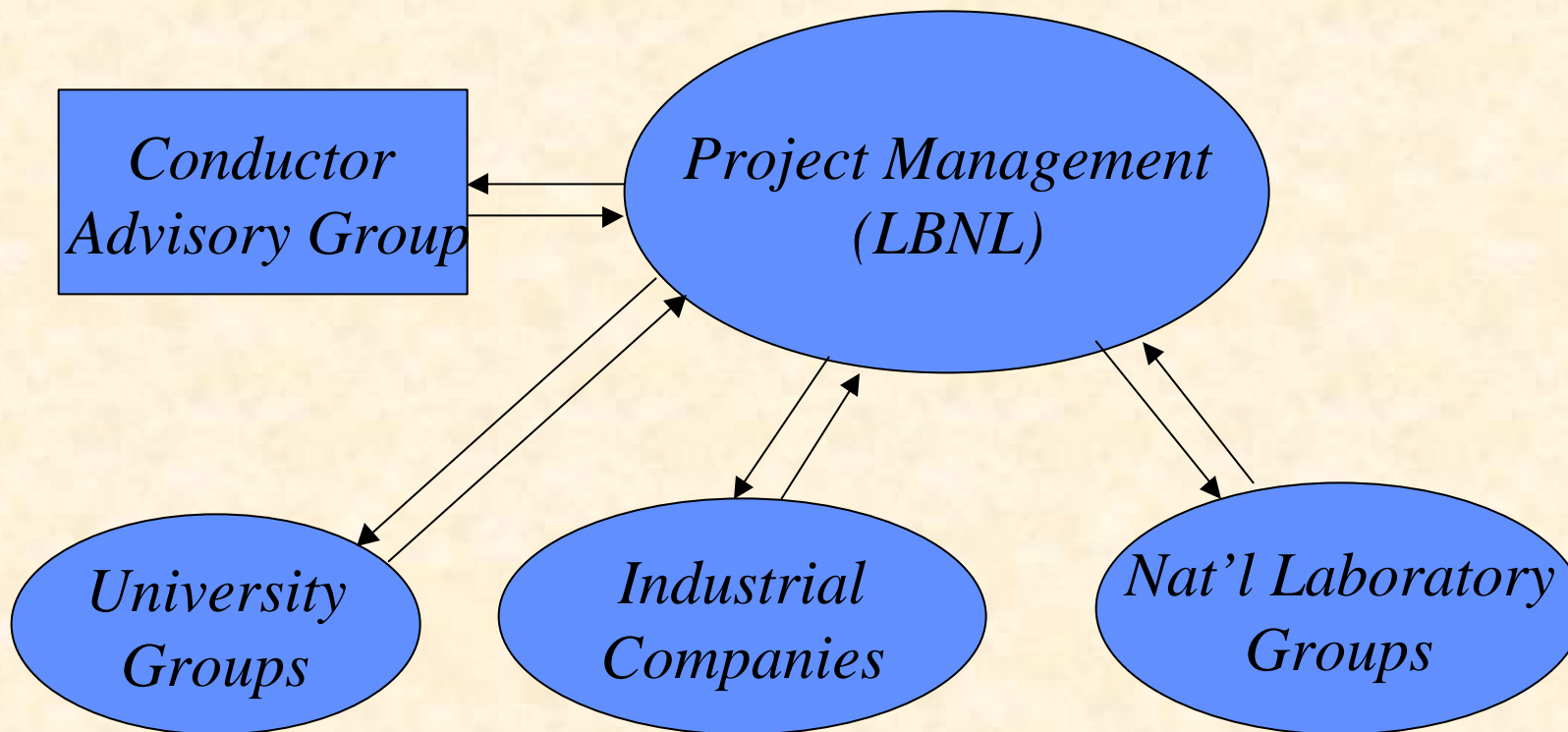
- ❑ Goals and Organization
- ❑ Work in Progress FY00(including Nb₃Al, supported by other funding)
- ❑ Plans for FY 01 and beyond

II. Base Program Materials Support

- ❑ Wire Procurement
- ❑ Cable Design and Fabrication
- ❑ Wire and Cable Testing



Conductor Development Program Organization





Lab and University Support for FY00 is coming from base program funds

- * BNL--Heat treatment
- * FNAL--Heat treatment, Ic tests
- * LBNL--Heat treatment, characterization, cable development
- * OSU-- Magnetization measurements
- * TAMU--Heat treatment
- * U. Wisc--Heat treatment, characterization, Ic tests

Total funding for FY00=\$500K; IGC+OST contracts = \$422K; LDRD=\$10K

LBNL Program Management (\$68K) is included in new Conductor Development Program funding



Conductor Development Program Goals

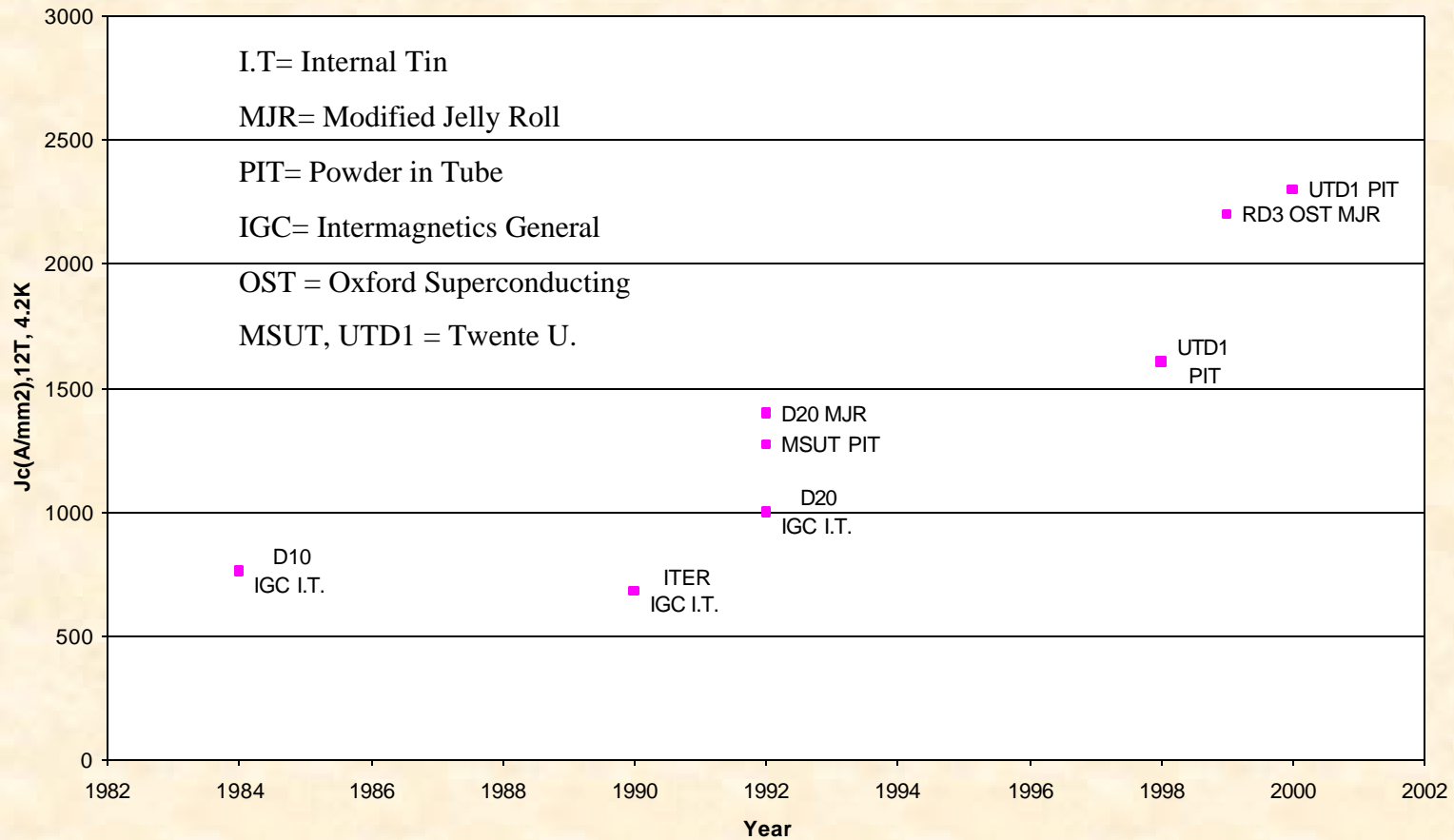
- ✿ Provide a cost-effective, high-performance superconductor of qualities not yet achieved for the high-field magnets required for the next generation high-energy physics colliders

- ✿ Target specifications for the HEP conductor include:
 - Jc (noncopper, 12T, 4.2 K): 3000 A/mm^2
 - Effective filament size: 40 microns or less
 - Piece length: Greater than 10,000 m in wire diam. of 0.3-1.0 mm
 - Wire cost: Less than \$1.50/ kA-m (12 T, 4.2 K)



Improvements in J_c for Nb_3Sn

Jc vs time
 Nb_3Sn





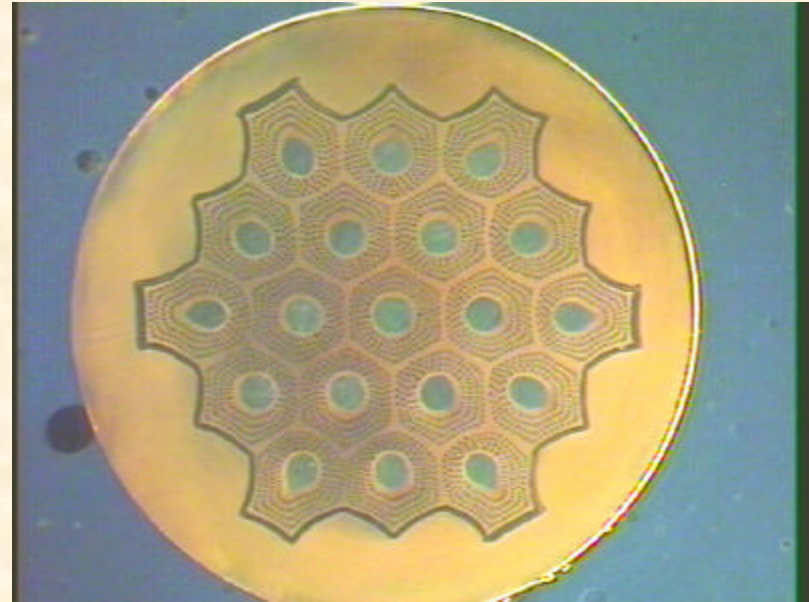
Technical argument for $J_c = 3000 \text{ A/mm}^2$

- ✿ Best (bulk samples) Nb_3Sn Layer $J_c = 5500 \text{ A/mm}^2$, 12T, 4.2 K
- ✿ Subdivide “non-copper” real estate as follows: 37% area fraction Nb, required to get 3000 A/mm^2 overall; 33% Cu matrix; 5% diffusion barrier; remaining 25% for Sn
- ✿ If this composite can be fabricated successfully, we should achieve a $J_c (\text{non-copper}) = 3000 \text{ A/mm}^2$
- ✿ This achievement will provide for cost-effective dipole magnets operating at fields up to 15 T



Oxford Superconducting Technology Goals

- ❁ Develop the Hot Extruded Rod (HER) process as a new, cost-effective alternative to their MJR process
- ❁ Determine J_c vs filament size relationship for HER process
- ❁ Optimize composition to give maximum J_c



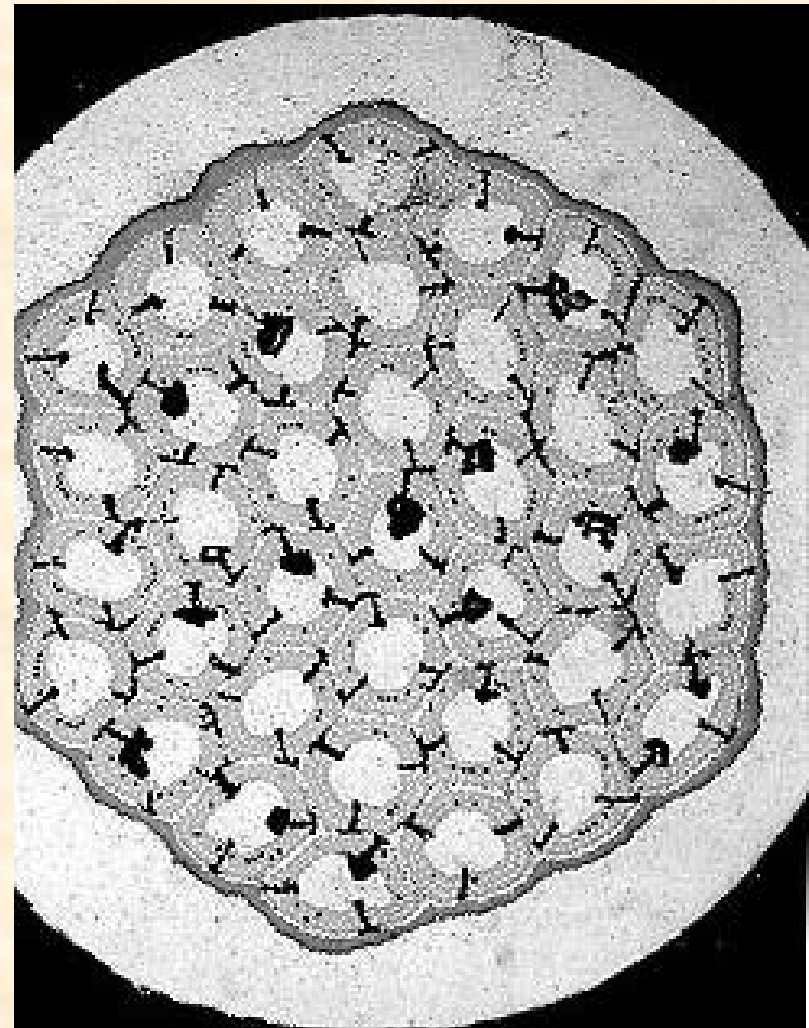
HER process billet after extrusion, before salt is removed from cores



Intermagnetics General Program Goals

- ❁ Optimize composition to maximize J_c in internal tin conductor
- ❁ Determine optimum split configuration to optimize J_c / filament size
- ❁ Optimize billet design to maximize wire lengths

3-split subelements in 61 stack after reaction (splits are now void regions)





STATUS OF HIGH TEMPERATURE RAPID QUENCH Nb₃Al PROGRAM

The Ohio State University

E.W. Collings, M.D. Sumption, F. Buta

EURUS

M. Tomsic

Collaborators

IGC Advanced Superconductors: E. Gregory

Supercon: T. Wong and M. Rudziak

The National High Field Magnet Laboratory: Y. Hascicek

The National Research Institute for Metals: A. Kikuchi, K. Inoue, Y. Iijima

The Tsukuba Magnet Lab: H. Wada, T. Takeuchi

The University of Wisconsin: B. Starch



FY 01 and beyond

- * Continue programs at IGC and OST
- * New Conductor Initiatives
 - Powder in tube RFP (anticipate 3-4 responses)
 - Nb₃Al Precursor Fabrication RFP (anticipate 3-4 responses)
 - Special processing facilities
- * Additional support for heat treatment, characterization, and Ic testing work
- * Scale-up key manufacturing steps to establish large scale processing costs
- * Develop realistic cost data to include in VLHC design studies



New Materials Program--Summary

- * New Materials Program is underway, with broad community support and participation
- * Two contracts are in place (IGC and OST)
- * Nb_3Sn manufacturers are using this as an opportunity to rebuild their development teams
- * I am optimistic that we can meet the performance and cost goals for Nb_3Sn



Strand procurement status

- ✿ Situation is much improved from May 1999.
- ✿ OST has delivered wire with $J_c = 2250 \text{ A/mm}^2$, with acceptable piece lengths:
 - 100 kg to LBNL in July 1999(=600mcable=RD-3)
 - 50 kg to FNAL in Dec 1999
 - 40 kg in final stages of processing for LBNL
- ✿ SMI has delivered strand with $J_c = 2250 \text{ A/mm}^2$, with acceptable piece lengths to FNAL in Feb 2000
- ✿ IGC has been able to improve piece lengths and to reproduce earlier high J_c results (1950 A/mm^2 at 12 T). Production for LBNL, FNAL, and TAMU has resumed.



Our cable design/fabrication work proceeds along two paths

- ✿ Empirical--design algorithms have been developed for mandrel, wire tension, narrow edge and overall compaction, etc. [H.Higley and H.vanOort]
--New algorithm developed for Nb_3Sn to reduce I_c degradation
- ✿ Analytical--FEM modeling with details of cable, strand, and filament arrays. Begun with H.vanOort's thesis; continuing with new student



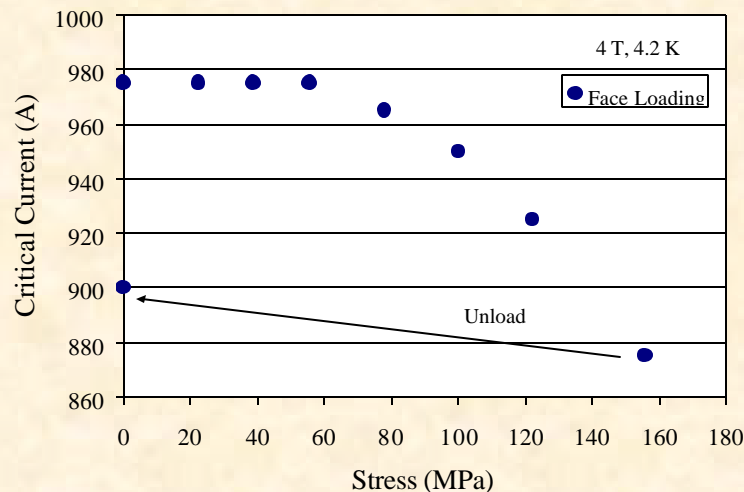
Cable verification testing

- ✿ Ic as a function of transverse strain at NHMFL-- determines cabling degradation and strain dependence of Ic
- ✿ Extracted strand tests at LBNL and Twente U.-- determines cabling degradation of Ic
- ✿ Ic vs field at BNL-- determines cabling degradation of Ic



New cable testing plans for NHMFL--subsize cables

I_c vs transverse stress for Bi-2212 strand cable



- ✿ Successful test at NHMFL facility in Nov 1999
- ✿ Note: 18 strand cable, 1 kA current range
- ✿ High current Nb₃Sn samples could not be tested during this run due to magnet quenching and current limits
- ✿ New Nb₃Sn subsize cables have been prepared to allow testing with degraded magnet at NHMFL



LBNL Cable Program Collaborations

- * Ohio State U--Contact Resistance and AC loss studies in NbTi, Nb₃Sn, Nb₃Al, and Bi-2212 strand cables
 - 16 joint publications in the past 5 years
 - cored cables developed by this collaboration have been adopted for use in Twente, Saclay, and FNAL programs
- * TAMU--design and fabrication of NbTi and Nb₃Sn cables for block magnet coils
- * BNL--new collaboration--Nb₃Sn cables for react/ wind studies. Bi-2212 cables for react/ wind common coils.

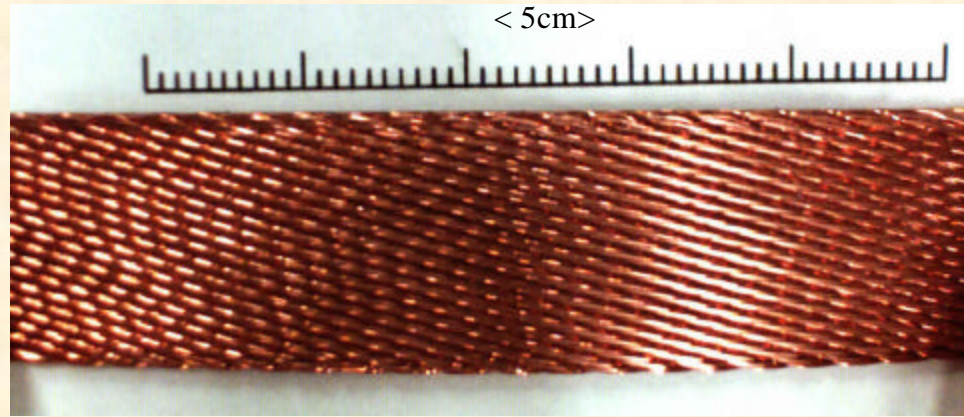
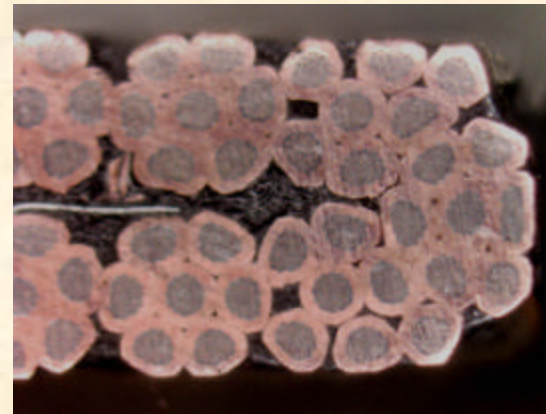
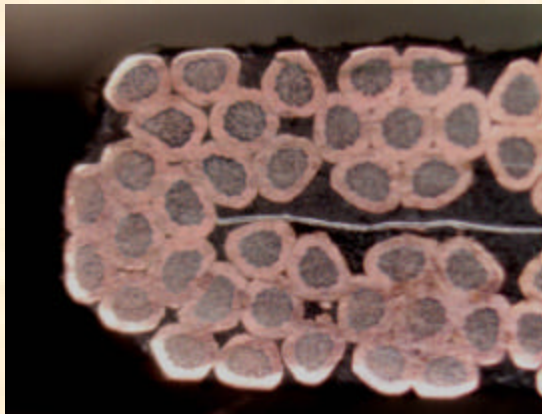
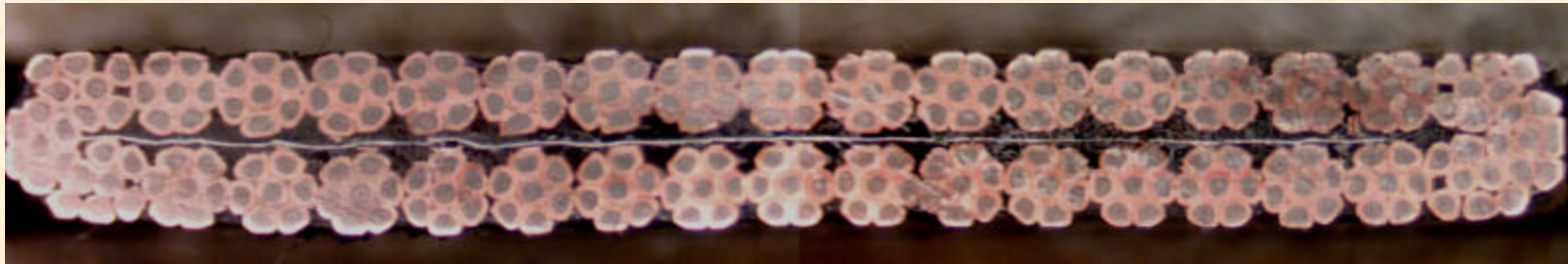


Cable collaborations (cont)

- ✿ FNAL--design and development of NbTi and Nb₃Sn cables
 - wide cables for quadrupole magnets (US LHC collaboration)
 - design and fabrication of Nb₃Sn cables for Cos theta dipoles (three long cables, 32 short samples)
 - design and fabrication of Nb₃Sn cables for react/ wind common coil (two long cables, 6 short samples)



FNAL R&W R3I-00741a Mfg. LBNL 2/17/00





Base Program Support--Summary

- * Conductor delivery/ performance situation for model coil programs has improved
- * We are beginning to build an inventory of high performance conductors for use in model coils
- * RT-1 test is in-coil verification of Nb_3Sn cable performance
- * New conductors are being developed for magnets beyond present generation models that are under construction at BNL, FNAL, LBNL, and TAMU (Mixed strand cables; HTS cables)